EECS 192: Mechatronics Design Lab

Discussion 5: Intro to Mechanical Design

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Encoder Demo

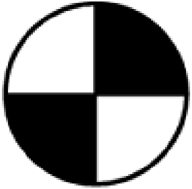
Motivation for Mechanical Design

Encoders

- Mount encoders somewhere on the car

Considerations

- Mechanical stability?
- Electrical connectivity?
- Time to build?



CG symbol (or could also be used as an encoder wheel)

source: autodesk.com

Rapid Prototyping

FDM (Fused Deposition Modeling)

Process

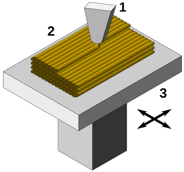
- Builds a model from the bottom up, layer-by-layer
- Deposits plastic by tracing the layer in plastic filament
- Infill generally not solid

Tradeoffs

- Materials: plastics, commonly PLA
  less commonly: ABS, PETG, flexible TPE, Nylon
- Speed: typically hours
- Quality: by layer height (trade time), minimum feature size by nozzle size

Prusa i3 mk3s printer

source: prusa3d.com



FDM printing process

source: Wikimedia, CC0

FDM: Design Rules

Mainly: consider overhang (depositing filament onto air)

- 30-45deg from vertical is fine
- Bridges can sag

Generally, complexity is "free", but:

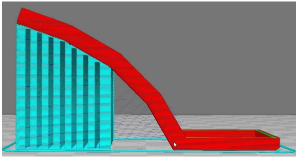
- Consider limitations from layer height and nozzle size

3d printed parts are anisotropic

- Layers shear easier

  inter-layer adhesion is weaker than filament strength

See the All3dp guide to designing FDM parts



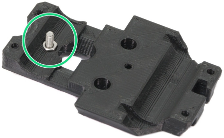
FDM printing process

source: Core Electronics

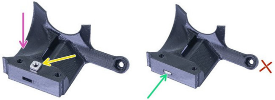
FDM: Ideas

Combining 3d-printed and mass-produced parts

- Friction-fit threaded nuts
- Heat-set threaded inserts
- Clearance holes for screws
- Embedding magnets / springs?



Hex nut friction-fit within part



Square nut inserted into the part

source: prusa3d.com

Related processes

- FDM is the most common process

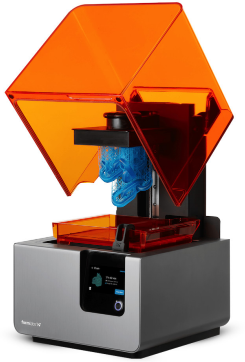
  Available in Supernode (pay-for-material), library makerspace (pay-for-material), Jacobs (semesterly makerpass)

- SLA (resin): laser cures layers in vat of photosensitive material; high-resolution

  Available in library makerspace (pay-for-material), Jacobs (semesterly makerpass + materials)

- SLS: laser selectively melts powder in layers Higher-end machines are metal capable

  Available in Jacobs for plastics (semesterly makerpass + materials)



Form 2 SLA printer

source: formlabs.com

Laser Cutting

Process

- Laser burns through a material
- or engraves, with lower power

Tradeoffs

- Materials: commonly plywood, acrylic
- Speed: very fast (minutes)
- Quality: limited by laser spot size
  up to 7mil (0.007 in)
- Limitations: 2d only

Laser cutting plywood

source: Sculpteo

Laser: Ideas

- Tab and slots to connect laser-cut pieces
- Living hinges to make curved surfaces
- Stacking laser-cut pieces as layers of a larger object

Tabs and living hinges

source: Thingiverse

Other Laser Cutting

- Most lasers are CO2, ~10um wavelength great on organic materials

  Available in CSWS (free training) and Jacobs (makerpass)

- Fiber lasers also exist, ~1um wavelength and can cut metal

  Available in and Jacobs (makerpass)

Jacobs FabLight metal-capable laser

source: Jacobs Hall bCourses

Machining Processes

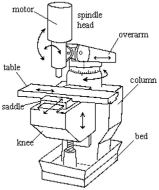
Machining (not-so-rapid prototyping)

Mill

- X, Y, and Z axes on a manual mill
- CNC mills can have 4, 5, or even 6 axes of freedom
- Good for rectangular / straight pieces

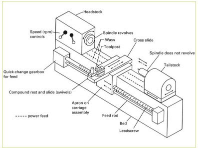
Lathe

- X, Y axes on a manual lathe
- Workpiece held in spinning chuck
- Good for round pieces



Mill

source: Making That



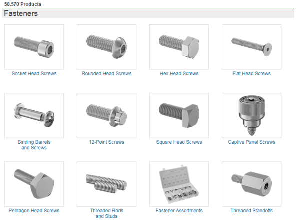
Lathe

source: Mechanical Engineering

Fasteners

Types of Fasteners

- Bolts & nuts
  - Common fasteners that you will be using in this lab.
- Glue
  - Epoxy – "permanent"
  - Hot Glue – less "permanent"
- Pressfit
  - Pieces interfere with each other mechanically and stay fastened by friction.
  - Requires excellent mechanical tolerancing or pliable materials (or both)
  - Tricky to design



Fasteners (bolts)

source: McMaster-Carr

Bolts & Nuts

- Selecting bolts & nuts
  - We use M3 fasteners in the lab.
  - M3 x 0.5: M3 is the thread diameter, 0.5 means 1 thread per 0.5mm
- Spacers
  - Washers – Usually thin (0.5mm, example)
  - Spacers – Usually longer (6mm, example)
  - Lock washers – Vibration resistance
- Nuts
  - Jam nuts – Convenient
  - Lock nuts – Vibration resistance

Standoff

source: McMaster-Carr

Standoff

source: McMaster-Carr

Mechanical CAD

Software

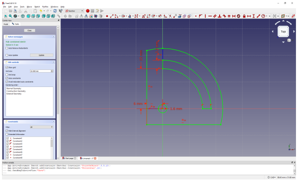
Many options for mechanical CAD software:

- FreeCad: free and open source, mostly competent (for hobby-level projects) even compared to commercial tools
  - Beginner 3d modeling tutorial
  - additional tutorials (focus on the Modeling Parts tutorials)
- Autodesk Fusion 360: commercial, free for personal use
- AutoCAD: commercial, available to Berkeley students free (?), reportedly good 2d support (?)
- SolidWorks: commercial, available in Jacobs CAD labs (?)

If you're familiar with one, keep using it.
Otherwise, FreeCAD or Fusion360 are probably your best bets for something you can use now and in the future.

Constraint-driven sketching

- Draw geometry (lines, arcs, ellipses,)
- Make constraints between them
  - Dimensions (length, radius, angle)
  - Horizontal / Vertical
  - Between-geometry: parallel, perpendicular, tangent
  - Can create construction geometry
- Constraints fully define the part



2d sketch with constraints in FreeCAD

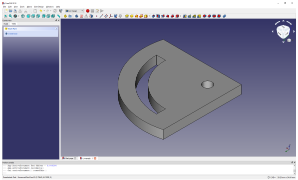
Parametric solid modeling

From 2d drawings

- Extrude 2d drawings into 3d
- Cut a 2d drawing from a 3d part
- Revolve a 2d drawing around an axis
- Loft through several 2d profiles

Modify 3d objects

- Replicate features: linear, axial, mirror
- Chamfer / fillet an edge
- Boolean operations between 3d objects: union, intersect, subtract



Sketch extruded into 3d shape

Exporting to fabrication

- Export to STL (mesh) for 3d printing
- Export to DXF or SVG (vector drawing) for laser cutting

Summary

Summary

- FDM 3d printing and laser cutting are the most accessible digital fabrication processes - try them!
- Use mechanical CAD software to design parts
- Use constraint-based sketching to make 2d drawings
- Then (optionally) extend them into 3d